Tinka Welke*, Susanne Raisig, Kati Nowack, Gesa Schaadt, Herbert Hagendorf and Elke van der Meer

Cooking from cold to hot: goal-directedness in simulation and language

Abstract: The present study explores the processing of temporal information in event knowledge by focusing on the transition from an earlier, source state to a later, goal state. Participants were presented with an event verb followed by antonymous adjectives or adverbs denoting an earlier state and a later state. The states were presented either chronologically (to cook: cold – hot) or inversely (to cook: hot – cold) with regard to the denoted event. Participants were asked to identify either the earlier or the later state. We found that later states are identified faster and more accurately than earlier states. Later states presented chronologically were identified even more quickly than later states presented inversely. We attribute our results to the fact that directedness towards the goal state is a general principle of cognition which plays a fundamental role in language and in simulation, whereby language processing provides faster and more direct access to goals even than simulation.

Keywords: language and simulation processing, event representation, event states, goal-directedness, chronology

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1 Introduction

Events are denoted by verbs, and the comprehension of event verbs has often been used as a means of investigating event knowledge in psychology (e.g., Altmann and Kamide 1999, 2007; Chatterjee et al. 1999; Ferretti et al. 2001; McRae et al. 2001). Processing a verb activates an event schema in which slots for thematic roles (or thematic relations) are opened up which are occupied by the persons and objects participating in the event (see Fillmore 1968; Hare et al. 2009; Lin and Murphy 2001; McRae et al. 1997). It has been shown that typical persons and objects and their thematic roles can be primed by an event verb (see, for example, Ferretti et al. 2001; Hare et al. 2009; McRae et al. 2005). The event verb *arrest*, for example, primes the typical agent *cop*. These priming effects demonstrate that the event schema extends to persons and objects.

The persons and objects which play the thematic roles in events are attributed states which also form part of event schemas. This is demonstrated by Ferretti et al. (2001), who showed that the event verb *trick*, for instance, primes *gullible*. Since the states of persons and objects change during an event, we suggest that a source and a goal state (such as cold and hot in *to cook*) are also included in event knowledge. Accordingly, Altman and Kamide (2009) propose that an event requires, "at a minimum, an initial state and an end state (with one or more participants in the event undergoing some change between the initial and end states)" (p. 56; see also Moens and Steedman 1988). When pasta is being cooked, for example, water will change its state from cold to hot, and the state of the person who eats the pasta will change from hungry to full. Cold and hungry are source states, hot and full are goal states.

In this study, we investigated processing of temporal information of events. In a *temporal judgment task*, participants had to decide either which one of two presented event states was the earlier state or which one of the two presented event states was the later state within a given event. To this end, participants were presented with an event verb followed by two antonymous adjectives or adverbs which respectively denoted the *earlier* (source) and *later* (goal) state of the event. The states were presented either in chronological order (early states on the left, late states on the right side on the screen; e.g., *to cook: cold – hot*) or in inverse order (late states on the left, early states on the right; e.g., *to cook: hot – cold*).

1.1 Simulation and language processing of events

One view of *embodied cognition* states that perceptual experiences are captured in association areas. When mentally processing these experiences, they are partially reenacted in the same overlapping neural tissue in which they were originally experienced (see the theory of perceptual symbol systems; Barsalou 1999). The resulting simulations are structured in the same way as the perceptual experience itself, and this may account for iconic representation (Barsalou calls perceptual symbols analogical, 1999: 578). Evidence of iconic representation is found in the study by Zwaan and Yaxley (2003) in which the spatial orientation of words on a screen was manipulated. The words, which denoted parts of objects such as *attic* and *basement*, were either presented iconically to their positions (*attic* was presented above *basement*), or inversely to their positions in the object (*attic* presented below *basement*). Participants were asked to judge whether the words were semantically related. Words in iconic positions were easier to identify as being semantically related than words in inverse positions.

When Louwerse (2008) re-analyzed the study by Zwaan and Yaxley (2003), he showed that the ease with which words positioned iconically on a screen (*attic* above *basement*) are processed as compared to words positioned inversely (*attic* below *basement*) is not just a direct effect of simulation, as Zwaan and Yaxley interpreted it to be, but may also be explained by a linguistic variable, namely the frequency of word order in language (the iconic order *attic* – *basement* is more frequent than the inverse order *basement* – *attic*). Louwerse (2008) concluded that relationships in language often serve as “a useful symbolic shortcut to embodied meaning” (p. 843; see also Louwerse 2007). We hasten to add that the fact that the more frequent word order mirrors iconically the spatial arrangement of object parts in reality is (probably) a result of the simulation retained in language. Accordingly, recent discussion has centered around a possible interaction between amodal and embodied cognition (e.g., Barsalou et al. 2008; Mahon and Caramazza 2008; Markman and Dietrich 2000).

In the language and situated simulation theory (LASS theory), for instance, Barsalou et al. (2008) propose that there are two systems of conceptual processing, a *linguistic system* and a *situated simulation system*. The two interact during conceptual processing, but one system dominates depending on the demands of the task. Barsalou et al. (2008) claim that only simulation permits access to the deep meaning of a concept, while the linguistic system processes concepts superficially (e.g., on word associations) and, thus, faster. When the linguistic system fails to suffice, the simulation system takes over and becomes dominant. This theory is supported by the results of a property verification task set by Solomon and Barsalou (2004) in which participants were asked to decide whether a property was part of an object or not (e.g., is *tusk* a property of an *elephant*?). Performance was mainly affected by perceptual variables of the properties such as size, salience and so on (i.e., variables which require processing in the simulation system). The tusk of an elephant, for instance, is larger than the nose of a fox. As a result, it takes longer to simulate and to verify it as a property of an elephant. In case of hasty responses, this process is also more erroneous.

Reaction times (RTs) and error rates indicating simulation of the properties of the object were only observed, however, when participants were presented in addition to actual properties with false properties that were highly associated with the objects in question (e.g., owl – tree). When participants were presented in addition to actual properties with false properties that were not highly associated with the objects (e.g., pliers – river), a superficial, linguistic association strategy was employed: Participants verified actual properties when an association with the paired object was detected – since all true part-object pairs are moderately to highly associated – and rejected false properties when no association was detected.

The linguistic strategy is indicated by RTs and error rates that were mainly affected by association strengths between the properties and the objects, but not by the perceptual variables. As a result, it leads to shorter RTs and fewer errors to verify a strongly associated property of an object than a moderately associated one. In contrast, where an association was perceived also between false properties and objects, it proved impossible to solve the verification task using the linguistic strategy alone, so participants resorted to mental simulation to permit deeper processing. The results obtained by Solomon and Barsalou (2004) strongly indicate that language processing is more efficient than simulation processing because not only were total verification times shorter but error rates were lower when the linguistic strategy was used.

The LASS theory is not only supported by RTs and error rates, but also by fMRI studies (e.g., Kan et al. 2003; Simmons et al. 2008). Using the property verification task (i.e., the task used by Solomon and Barsalou 2004; see above), Kan et al. (2003) found that the left fusiform gyrus (an area which is commonly associated with imagery processes) was activated when the property-object pairs used in the false trials were associated, indicating simulation processing (cf. Barsalou et al. 2008). However, the left fusiform gyrus was not activated when the property-object pairs used in the false trials were not associated, indicating that no imagery processes were involved. This result demonstrates that language processing sufficed when the property-object pairs used in false trials were not associated.

1.2 Goal-directed representation of events

On the basis of the LASS theory (Barsalou et al. 2008), we assumed that asking participants to identify either the earlier state or the later state would activate both the linguistic and the simulation system, but that their relative impact would vary depending on the instructions received. We suggest that goals are salient in both systems. Focusing on the end states (goals) of events is one of life's main principles. We are always trying to anticipate and predict the goals of events that will occur in the future.

Language serves to reorganize our perception of events according to intentions and goals (Zacks et al. 2001). Language is a means to support anticipation and goal-directed cognition (Zwaan 2008). When a pencil is being sharpened, for instance, we cannot see that the pencil has become sharp until we have finished rotating it in the sharpener. However, by the means of language we can infer that rotating the pencil serves the goal of sharpening it. That goal-directedness is a fundamental aspect of language is evidenced by the fact that a distinction is made between telic and atelic verbs – verbs that implicate an end (a goal) and verbs that are not biased towards an end. Telic verbs (like *to build* and *to destroy*) are goal-directed, as the very name suggests. Atelic verbs, on the other hand, such as *to live* and *to love*, don't involve an endpoint (see Vendler 1967 and Dowty 1979) and thus are not goal-directed.[1]

Telic verbs have a strong linguistic association with the goal state of the event they refer to (cf. *cook* – *hot*). We argue that this linguistic association enables goals to be anticipated rapidly. When participants are instructed to identify the later state (i.e., the goal state of an event), then, the event verbs presented on the screen are assumed mainly to trigger the linguistic system. Although the linguistic system is also active when participants are instructed to identify the earlier state (after all, the stimuli are words – see the encoding specificity principle of Tulving and Thomson 1973; cf. also Barsalou et al. 2008), earlier event states do not bear such a strong linguistic association with the event verb and so cannot be processed effectively by the linguistic system alone. Instead, the event and its states have to be simulated. This process is more challenging and more time consuming. This is why we assumed that RTs would depend on the instructions received, and that later states (accessed primarily via language processing) would be identified faster than earlier states (which are accessed primarily via simulation). Because the simulation system is goal-directed too, however, we assumed that responses to earlier states would not only take longer but also be less accurate than responses to later states. If this was the case, it could indicate a way in which the two systems are reconciled.

1 This typology is fundamental in language philosophy as well as in linguistics. The line between telic verbs and atelic verbs is a fine one, but there are means of coercing verbs into telic and vice versa (see Moens and Steedman 1988).

Fig. 1: The chronological and directed representation of events places emphasis on goals

1.3 Processing chronology by simulation

Directedness towards the future also implies that the *chronological order* of events is retained in our mental representation of them (see Fig. 1). Several studies have shown that component events of event sequences (i.e., scripts; cf. Schank and Abelson 1977) are represented in chronological order (e.g., Barsalou and Sewell 1985; Raisig et al. 2007, 2010; van der Meer et al. 2006). Furthermore, violations of chronological order also affect memory performance in recall: Non-chronological script events were recalled incorrectly, with a bias towards chronological order (Bower et al. 1979). In line with previous findings, we expected the order in which event states were presented to have an effect on RTs and accuracy, with chronological presentation eliciting faster and more accurate responses than inverse presentation.

According to the embodied cognition theory, knowledge preserves the perceptual and motoric properties of the represented entities iconically (e.g., Barsalou 1999; Barsalou 2008; Glenberg 1997; Zwaan and Madden 2005). The simulation of events should thus preserve the chronological order of event states. A strong linguistic association exists between event verbs and later states, which enables later states to be identified via language processing. Thus, we did not expect the order of presentation to have a significant effect in the case of later states. Instead, we assumed that simulation would only be required when identifying earlier states. As a result, the effect of the order in which states are presented is expected to be significant only when participants are asked to identify earlier states – that is, earlier states are likely to elicit faster and more accurate responses when presented chronologically (i.e., on the left side of the screen) than when they are presented inversely (i.e., on the right side of the screen).[2]

2 Note, that since we presented each order of adjectives both chronologically and inversely with regard to an event verb (cf. Table 2), an impact of temporal order cannot be attributed to directed associations between the antonymous adjectives.

In line with Nuthmann and van der Meer (2005), we varied the stimulus onset asynchrony (SOA) between the onset of presentation of the event verb and the onset of presentation of the event states using intervals commonly associated with automatic and strategic processing (250 ms and 1000 ms). A short SOA of 250 ms does not allow sufficient time for strategic processing in semantic priming paradigms (Neely 1977; cf. de Groot 1984). Nuthmann and van der Meer (2005) found evidences that single event representations are directed toward the goal state of an event. Participants had to decide whether a verb denoting an event (e.g., *piling*) was related to an adjective or participle denoting a source state of an object (e.g., *low*), or to an adjective or participle denoting a goal state of an object (e.g., *high*). Under both SOA conditions, participants were faster to verify the relatedness of a goal state than that of a source state. Regarding error rates, however, goal states were only responded to significantly more accurately under the long SOA (and not under the short SOA) suggesting that, under the long SOA, goal-directed representation is strengthened by the strategic prediction of goal states. This results in the erroneous rejection of source states as being unrelated. On the basis of this outcome, we used the same SOA variations to explore whether the SOA would affect the processing of the goal-directed representation of the event.

To summarize, our main hypotheses were: (a) Later states will be identified more quickly than earlier states independently of the order in which the states are presented because later states are the goals of an event and can be processed linguistically, whereas the identification of earlier states requires simulation processing. (b) Earlier states will be identified less accurately than later states because in simulation processing goals are salient. (c) Earlier states presented chronologically will be identified faster and more accurately than earlier states presented inversely. (d) If the SOA variation affects the effects of instruction or order of presentation on RTs or error rates, this can be taken as an indication that strategic processes modify the relative impact of goal-directedness for event representations.

2 Methods

2.1 Participants

Thirty-eight psychology students from the Humboldt University Berlin participated in this study. All were native German speakers. Twenty-eight were female. Participants either received credit points or participated voluntarily.

The mean age was 24 years; SD = 6.5. We adhered to the tenets of the Helsinki Declaration.

2.2 Material

To create the material for the present study, we first gathered antonymous adjectives or adverbs that denoted source and goal states of an event, for example, *cold – hot*. The antonyms denoted a transition in a particular direction, in this case from *cold* to *hot*. In the following pre-test, by pressing a ctrl-button, 20 participants (mean age 25.5, SD 3.9) judged whether the two adjectives/adverbs were meaningfully related or not. Mapping between the answer and the left and right ctrl buttons was counterbalanced between subjects. The pre-test consisted of 50% antonymous adjectives or adverbs and 50% adjectives or adverbs without a semantic relationship (i.e., distracters, e.g., *light – small*). To control for possible order effects, the two adjectives/adverbs were presented in both orders (*small – broad* and *broad – small*).

The meaningfully related antonyms that we had identified as adequately describing event states were next placed on two lists, appearing on each list in a different order (e.g., list 1 *cold – hot*, list 2 *hot – cold*). Each list was then given to 10 participants (mean age 36.3, SD 14.28) who were asked to generate event verbs for each antonym pair, respecting the chronological order in which the antonyms were presented (e.g., it was stressed that the antonym pair *small – broad* could describe the transition of states that takes place during the events *to enlarge, to fatten* or *to dilate*, but not that which takes place during the events *to narrow* or *to compress*). Seventeen new participants (mean age 29.9, SD 8.9) ranked the events thus generated according to how well they fitted the antonyms describing the transition between event states from 1 for the best rank to higher values for lower ranks (depending on the number of events generated per antonym order). Those events with the lowest median values (i.e., the best rank) were selected for the present study.[3]

3 The verbs we selected were coerced into telic by the adjectives or adverbs which followed. One of the two states which participants were instructed to identify referred to the end of the event, ensuring that the verbs were clearly understood as telic. This was confirmed by an association test conducted post-hoc (see Discussion) which revealed an association strength of .71 between event verbs and adjectives/adverbs (or synonyms thereof) which denoted the state resulting from the event (goal state). The association strength between verbs and goal states was balanced across the orders in which the denoting antonyms were presented in the main study, $t(31) = 1.16$, $p = .25$, $r = .2$.

Finally, each antonym pair was combined with the event verb that reflected the chronological order in which the antonyms were presented. To give an example, the event verb *to freeze* reflects the chronological order of the antonym pair *hot – cold*, while the event verb *to cook* reflects the chronological order of the antonym pair *cold – hot*. By inversing the order of the antonyms and assigning them to the same verb, we then also created the inverse condition (e.g., *to freeze: cold – hot;* cf. Table 1). In the end we were left with a total of 64 event verbs paired with 32 antonym pairs that were used in both orders (e.g., *to enlarge: small – broad* and *to narrow: broad – small*; cf. Appendix). The study was conducted in German. The examples above are translations into English.

2.3 Design

Each event verb was used twice, once in connection with antonyms that denoted states in chronological order, once in connection with antonyms that denoted states in inverse order. To avoid participants being presented with the same event verb twice, stimuli were assigned to two lists, each containing 64 events, with 50% of the events on each list presented in connection with chronologically ordered states and 50% with inversely ordered states (e.g., list 1 *to cook: cold – hot*, list 2 *to cook: hot – cold*). Since the same antonyms were used each time, just in a different order, word frequency and number of syllables were controlled for.

The following independent variables were included in the study:

1. Instructions were a blocked factor: For one half of the stimuli (N = 32) participants responded to instructions regarding earlier states, for the other half of the stimuli participants responded to instructions regarding later states. The order of blocks was counterbalanced, so that 19 of the 38 participants

Table 1: Event States Presented in Chronological and Inverse Order (English translations are given in parentheses)

Event verb	**Event states**	
	Chronological	**Inverse**
ausstrecken	*kurz – lang*	*lang – kurz*
(to extend	short – long	long – short)
abschneiden	*lang – kurz*	*kurz – lang*
(to cut	long – short	short – long)

Note. By constructing the stimuli, we ensured that no event verb shared word forms with the event states

first responded to earlier states and 19 participants first responded to later states.
2. Temporal order: For each instruction block 50% of the states were presented in chronological order, 50% in inverse order. Within each block, items were presented in random order.
3. SOA: Fifty percent of participants were tested with an SOA of 250 ms, 50% with an SOA of 1000 ms.

The dependent variables were RTs and error rates.

2.4 Procedure

The experiment was carried out using the stimuli delivery and experiment control program *presentation* (Version 12.1 for Windows). The experiment took place in a laboratory. After participants had taken their seat, they read the instructions presented on a computer screen. The instructions described the temporal judgement task and directed participants to answer the questions which would follow as accurately but as quickly as possible. The questions concerned were either “Which state comes earlier within the event?” or “Which state comes later within the event?” In the first block, participants were requested to answer one of the questions. When they had finished, further instructions appeared in which participants were requested to answer the other question. Each block began with eight practice trials for which participants received feedback (“Correct!”, “Wrong!”). These practise trials were not included in the data analysis.

Presentation of each event verb was preceded by the appearance of a fixation cross in the centre of the screen (cf. Figure 2). Subsequently, the verb was shown, also in the centre of the screen, for either 250 ms or 1000 ms (SOA) before being replaced by an antonym pair denoting the two event states. The event states were presented to the left and right of the centre of the screen (the centre of each being 113 mm from the mid-point of the screen). From this time onwards RTs were recorded. The left and right “control” keys on a standard computer keyboard served as the response buttons. To indicate their response, participants were instructed to press the response button on the side on which the requested state was shown. As soon as the participant had given a response, the antonyms disappeared and were masked for 2000 ms with series of *x*. A smiley on the screen then signalled a short pause before participants were able, at their own pace, to carry on by pressing one of the “control” keys. The experiment lasted about 20 minutes.

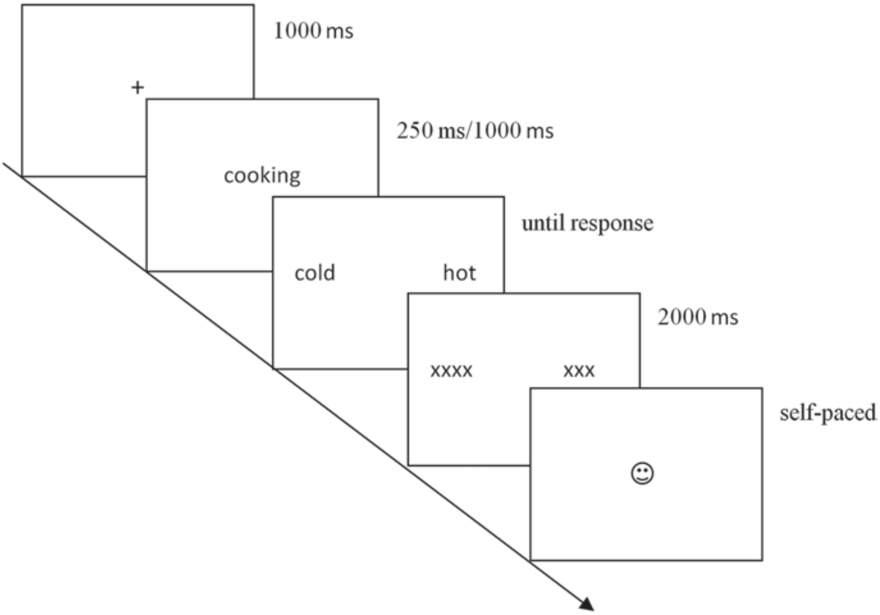

Fig. 2: Time course of an experimental trial. RTs were measured from onset of the antonym until a response was given

2.5 Data analysis

Data pertaining to RTs and error rates was analysed using SPSS (Statistical Package for the Social Sciences, versions 11.0 and 14.0). Errors were excluded from the analysis of RTs. RTs that were greater or smaller than three standard deviations from the arithmetic mean of a participant's RTs under each condition were removed (1.6%).

The data was analysed using a three-way mixed ANOVA (analyses of variance).[4] Two factors were analysed within-subjects: instructions received (earlier vs. later depending on which state participants were instructed to identify) and temporal order of states (chronological vs. inverse depending on the order in which the states were presented). SOA was included as a between-subjects factor

4 We only report subject analyses here. Since each instruction block (earlier state, later state) featured the same items in both temporal orders (chronological, inverse), item analyses are not required (Raaijmakers et al. 1999).

Table 2: Mean Reaction Times (RT, in milliseconds, ms) and Error Rates (ER) with Standard Error of Each Mean in Parentheses (SE) for Interaction Between Instructions Received, Temporal Order of Presentation of States, and SOA (250 ms vs. 1000 ms)

Instructions *SOA*	**Temporal order**			
	Chronological		**Inverse**	
	RT	**ER**	**RT**	**ER**
Earlier state				
250 ms	1833.63	0.16	1773.84	0.1
	(90.91)	(0.03)	(86.16)	(0.03)
1000 ms	1643.27	0.15	1618.89	0.13
	(90.91)	(0.02)	(86.16)	(0.02)
Later state				
250 ms	1394.90	0.09	1531.12	0.07
	(80.91)	(0.03)	(87.45)	(0.03)
1000 ms	1284.40	0.08	1387.74	0.1
	(80.91)	(0.02)	(87.45)	(0.02)

(250 ms vs. 1000 ms). The level of significance was set at $p < .05$. Where interactions related to our original hypotheses were detected, we conducted Bonferroni-Holm corrected *t*-tests (cf. Bühner and Ziegler 2009) to compare groups within each factor level. All analysed data sets were normally distributed.

3 Results

Table 2 shows RTs and error rates according to instruction, temporal order and SOA. We will first report the main effects of instructions and temporal order and subsequently their interaction. Finally, we will report potential moderation of the main effects by the SOA.

The ANOVA yielded a main effect of instruction on RTs, $F(1, 36) = 40.88$, $MSE = 93925.17$, $p < .001$, $\eta_p^2 = .53$ and error rates, $F(1, 36) = 11.73$, $MSE = .01$, $p < .01$, $\eta_p^2 = .25$. Later states were identified significantly faster and more accurately than earlier states regardless of the temporal order in which the states were presented.

The interaction between instruction and temporal order was significant for RTs, $F(1, 36) = 8.86$, $MSE = 28094.46$, $p < .01$, $\eta_p^2 = .2$ (cf. Figure 3) but not for error rates, $F(1, 36) = .96$, $MSE = 0.02$, $p = .17$, $\eta_p^2 = .05$.

In order to find out where the interaction effect in RTs stemmed from, we conducted paired *t*-tests to compare the chronological and inverse presentation

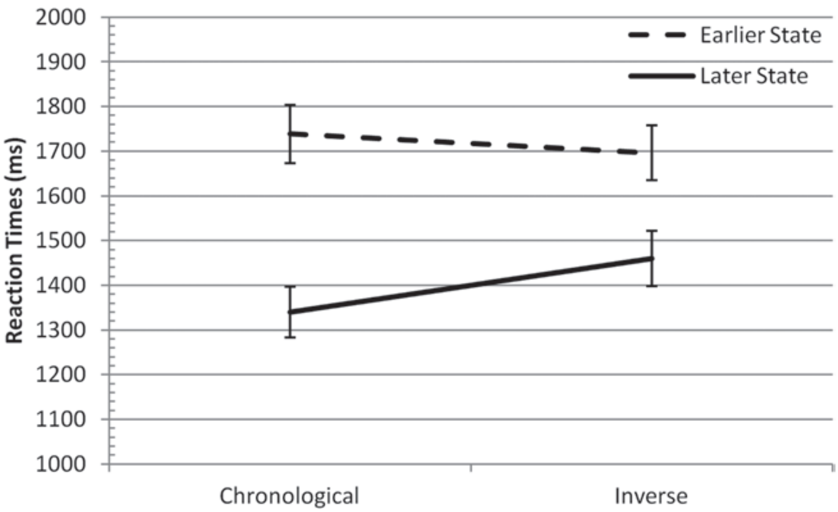

Fig. 3: The graphs demonstrate the interaction between the factor "instructions received" (identify earlier vs. later state) and the factor "temporal order of presentation" (chronological vs. inverse). Each point shows mean ± 1SE

of states for both instruction blocks (identify earlier state/identify later state) separately. Chronologically presented later states (i.e., later states on the right-hand side of the screen) were identified significantly more quickly (1340 ms) than later states presented inversely (i.e., on the left-hand side of the screen; 1459 ms), $t(37) = -3.32$, $p < .01$, $r = .48$. However, the order of presentation had no effect on the speed of identification of earlier states, $t(37) = 1.05$, $p = .3$, $r = .17$.

Further, when only chronologically presented states were considered, later states were identified significantly faster, $t(37) = -7.3$, $p < .001$, $r = .77$, and more accurately than earlier states, $t(37) = 3.21$, $p < .025$, $r = .47$. When only inversely presented states were considered, later states were still identified significantly faster than earlier states, $t(37) = 4.12$, $p < .001$, $r = .64$, but not significantly more accurately, $t(37) = 1.48$, $p = .15$, $r = .24$.

With regard to the interaction between instruction and SOA, the analysis revealed no statistically significant effect on either RTs, $F(1, 36) = 0.21$, $MSE = 93925.17$, $p = .65$, $\eta_p^2 = .01$, or error rates, $F(1, 36) = 0.01$, $MSE = -0.00007$, $p = .93$, $\eta_p^2 = .00$. An analysis of the interaction between order of presentation and SOA did not reveal a significant effect on RTs, $F(1, 36) = 0.00$, $MSE = 28104.69$, $p = .98$, $\eta_p^2 = .00$ or error rates, $F(1, 36) = 1.48$, $MSE = 0.016$, $p = .23$, $\eta_p^2 = .04$ either. Neither did an analysis of the three-factorial interaction between instruction, order and SOA reveal a significant effect on RTs, $F(1, 36) = 0.39$, $MSE = 28094.46$, $p = .53$, $\eta_p^2 = .01$ or error rates, $F(1, 36) = 0.01$, $MSE = 0.00008$, $p = .93$, $\eta_p^2 = .00$.

4 Discussion

The aim of this study was to investigate the processing of temporal information of events by the means of the transition from a source state to a goal state. According to the LASS theory of Barsalou et al. (2008), both the efficient linguistic and the more elaborative simulation system were assumed to be involved differently in the processing temporal information depending on the instruction (i.e., identifying the earlier or the later state).

The study yielded the following main results. Firstly, being asked to identify later states led to significantly faster RTs and significantly lower error rates than being asked to identify earlier states regardless of the order in which the states were presented on the screen (chronological vs. inverse). Secondly, later states were identified more rapidly when they were presented in chronological order than when they were presented in inverse order. Thirdly, the identification of earlier states was not affected by the order in which the states were presented. All significant effects were observed independently of the SOA.

Our results show that later states clearly enjoy a processing advantage. This supports the notion of the goal-directedness of cognition (Barsalou 2009; Hommel et al. 2001; Prinz 1997).

4.1 Emphasizing goals in language

According to the LASS theory (Barsalou et al. 2008), the simulation system and the linguistic system act together but to differing extents. There is striking evidence that goal-directedness is implemented and stressed in both the linguistic system and the simulation system, as we will outline in the following discussion. The linguistic system is more efficient than the simulation system, that is, it processes concepts at lower cognitive cost. The goal-directedness of the linguistic system is highlighted by features of language such as telic verbs. When a telic verb (e.g., *to lock*) is processed, a linguistic representation of the event is activated which points to the goal state. We argue that consequently, when participants were asked to identify later states, the linguistic system dominated, speeding up the response process. The effectiveness of the linguistic system in identifying later states is illustrated by the result that later states were identified faster and more accurately than earlier states irrespective of the order in which the two states were presented. When identifying earlier states, however, we argue that the simulation system is essential. Simulation is more challenging because sensory processes are involved, and this is reflected in the longer processing times observed when earlier states had to be identified. Since the advantage of later states emerges under both SOAs, we conclude that the goal-directedness remains robust under a short and a long SOA.

We explain the role of the linguistic system in responding to later states by proposing an association between event verbs and later states. The classical view of association is based on normative free association tasks. Association is generally deemed to a high probability of response (see also Hutchison 2003). We used a restricted association task to prove post-hoc association strengths between event verbs and later states and between event verbs and earlier states. We encouraged 10 participants to come up, in response to event verbs, with adjectives or adverbs but not nouns.[5] Among the first five associations generated by each participant, the mean frequency of verb-goal state associations was much higher (0.71) than the mean frequency of verb-source state associations (0.14). This confirms that goals are more strongly associated with event verbs than source states are. The lesser association strength between event verbs and earlier states are not sufficient to anticipate the earlier state only linguistically.

Please note that we do not distinguish between linguistic association and semantic content as Barsalou et al. (2008: 251) do. According to Barsalou et al., "language *per se* cannot represent a concept" (p. 266), which implies that the simulation system is the only one to take account of semantic content. We propose instead that associations processed in the linguistic system are based on semantics. They are linguistically mirrored co-occurrences of things and properties in real life (e.g., broom-floor, canary-yellow). Hence, language does encode real relationships between things (cf. Louwerse 2007). This is indicated by a study by Prior and Bentin (2008) who demonstrated that associations between words were only learned when they were embedded in coherent sentences and not when they were embedded in semantically non-sense sentences, showing that pure co-occurrences of words do not suffice to build associations. Consequently, the goal states we obtained in our restricted association task are assumed to be related to the semantic content of event verbs and, thus, cannot be seen as associations without semantic content.[6]

5 In normative free association tasks, nouns are most frequently associated with verbs and only rarely are state-denoting adjectives or adverbs obtained (Nuthmann and van der Meer 2005; Strube 1984). For this reason we used a restricted association task here.

6 For a more elaborate investigation of the role of association in event knowledge, see Hare et al. (2009).

Similarly, very recent studies attempt to reconcile embodied and linguistic accounts of the representation of semantic content (Andrews et al. in press; Borghi and Cimatti 2012) and outline how words function as "tools" (Borghi and Cimatti 2012) for accessing meaning both through their linguistic relationship to other words and their embodied grounding in experience.

4.2 Goal-biased simulation

We expected the order in which the antonymous adjectives or adverbs were presented to have an effect on RTs and accuracy, especially where participants had been instructed to identify earlier states. Contrary to our expectations, however, the order effect was only present in connection with later states. Later states presented in chronological order were identified more rapidly than later states presented in inverse order (remember that a temporal order impact cannot be attributed to directed associations between the antonymous adjectives, see Note 2). We attribute this effect to the efficiency achieved when linguistic and simulation processing are combined. Though the linguistic system peaks first when later states have to be identified, the simulation system is not inactive but ready to kick in subsequently (see Barsalou et al. 2008: 248). This dual processing speeds up the identification of chronologically presented later states compared to inversely presented later states.

Goal-directedness is a phenomenon that fundamentally influences the perception and memorization of events (e.g., Barsalou and Sewell 1985; Hommel et al. 2001; Klein et al. 2010; Kurby and Zacks 2008; Zacks et al. 2001), so it would be surprising if it were not present in simulation. Selective attention is focused on schematic components of perceptual experiences that become part of the long-term memory, meaning that simulations themselves are "always partial and sketchy, never complete" (Barsalou 1999: 586). Thus, events are generally simulated focussing on goals because this is the important aspect for cognition.

The question remains, however, of why earlier states presented in chronological order were not identified more rapidly than earlier states presented in inverse order. This seemingly paradoxical result we too attribute to the fact that during simulation processing, attention is biased to goal states, subjecting source states to a general processing disadvantage even when they are presented chronologically. Because simulation processing is goal-biased, perception in our experiment is directed towards the *right-hand side* of the computer screen where the goal of an event is expected to be, irrespective of whether the state in question is the earlier or the later state. This expectation is fed by the correlation between later states that are goals and the right side of the screen in iconic chronological order.

The attentional bias to the right is indicated by significant shorter RTs to states presented on the right than to states presented on the left, not only for later states, but irrespective of the state in question, $t(37) = 2.81$, $p < .01$, $r = 42$.

The goal-bias is also reflected in the higher error rate generally observed when participants were asked to identify earlier states. Only after the goal state has been detected can the earlier state be inferred on the basis of that goal. In line with this conclusion, Lichtenstein and Brewer (1980) found evidence that to retrieve temporal information, people work back from the goal to the sub-goals that constitute the "preconditions" (i.e., the source states) of superordinate goals in a hierarchical order (p. 428).

Our evidence that the goals or end states of events are emphasized in perception as well as in language is supported by a study by Regier and Zheng (2007), who asked participants to judge whether two events shown in video clips were the same. The events presented either emphasized the beginning (e.g., taking a cap off a pen) or the end of an event (e.g., putting a cap on a pen). Participants made fewer errors when judging the ends of events than when judging the beginning of events, indicating that people particularly focus their attention on event endpoints (p. 709). Regier and Zheng (2007) also found an attentional bias to the ends of events in language. When participants were asked to describe events, finer semantic distinctions were made at event endpoints than at event beginnings.

In a nutshell, we assume that goal-directedness is found in both the simulation system and the language processing system. It features in the simulation system because it is a fundamental principle of survival, and is retained for the same reason in a more abstract form in the linguistic system.

5 Conclusion

During an event, the states of persons and objects change. We used this as a means of investigating the way in which events are represented mentally. On the basis of a temporal judgement task, we showed that earlier (source) states and later (goal) states are not represented and accessed in the same way.

The explanation for our results lies in the interplay between the simulation system and the linguistic system (see the LASS theory; Barsalou et al. 2008). In accordance with Barsalou (2009) and Hommel et al. (2001), we showed that goal-directedness is both a guiding principle of cognition and one which explains how events are represented. Goal-directedness (i.e., directedness towards later states) is represented by both systems. However, the linguistic system provides faster and more direct access to goals and later states, making it easier to identify later states than earlier ones in both orders in which the two are presented. The influence of the simulation system means that later states presented chronologically are processed faster than later states presented inversely. Responses to earlier, source states are always delayed, less accurate and not facilitated by chronological presentation because simulation itself is goal-directed and attention is biased towards the goal at the end. Before the source state can be identified, then, goal-directedness has to be overcome.

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Appendix

German Version			English Translation		
Event	**Antonym 1**	**Antonym 2**	**Event**	**Antonym 1**	**Antonym 2**
abschmecken	*ungenießbar*	*bekömmlich*	to taste	*inedible*	*digestible*
verfaulen	*bekömmlich*	*ungenießbar*	to go mouldy	*digestible*	*inedible*
festschrauben	*wackelig*	*stabil*	to screw	*unstable*	*stable*
lockern	*stabil*	*wackelig*	to loosen	*stable*	*unstable*
auskurieren	*krank*	*gesund*	to cure	*ill*	*healthy*
infizieren	*gesund*	*krank*	to infect	*healthy*	*ill*
aufrichten	*waagerecht*	*senkrecht*	to erect	*horizontal*	*vertical*
umkippen	*senkrecht*	*waagerecht*	to capsize	*vertical*	*horizontal*
beschädigen	*heil*	*defekt*	to damage	*intact*	*broken*
reparieren	*defekt*	*heil*	to repair	*broken*	*intact*
anpassen	*verschieden*	*gleich*	to match	*different*	*same*
verändern	*gleich*	*verschieden*	to alter	*same*	*different*
erhöhen	*billig*	*teuer*	to increase	*cheap*	*expensive*
ermäßigen	*teuer*	*billig*	to reduce	*expensive*	*cheap*
zerschmelzen	*gefroren*	*abgetaut*	to melt	*frozen*	*thawed*
erkalten	*abgetaut*	*gefroren*	to cool	*thawed*	*frozen*
zurückkommen	*dort*	*hier*	to return	*there*	*here*
auswandern	*hier*	*dort*	to emigrate	*here*	*there*
erweitern	*schmal*	*breit*	to enlarge	*narrow*	*broad*
einengen	*breit*	*schmal*	to narrow	*broad*	*narrow*
entwirren	*komplex*	*einfach*	to disentangle	*complex*	*simple*
zusammensetzen	*einfach*	*komplex*	to compose	*simple*	*complex*
komplizieren	*leicht*	*schwer*	to complicate	*easy*	*difficult*
unterstützen	*schwer*	*leicht*	to assist	*difficult*	*easy*

German Version			English Translation		
Event	Antonym 1	Antonym 2	Event	Antonym 1	Antonym 2
entzweien	*auseinander*	*zusammen*	to divide	*joined*	*separate*
vereinen	*zusammen*	*auseinander*	to join	*separate*	*joined*
auszehren	*fett*	*mager*	to become emaciated	*fat*	*skinny*
zunehmen	*mager*	*fett*	to gain weight	*skinny*	*fat*
gebären	*innen*	*außen*	to give birth	*inside*	*outside*
eintreten	*außen*	*innen*	to enter	*outside*	*inside*
anzünden	*erloschen*	*brennend*	to inflame	*extinguished*	*burning*
ausglühen	*brennend*	*erloschen*	to cease glowing	*burning*	*extinguished*
verschließen	*auf*	*zu*	to close	*open*	*closed*
öffnen	*zu*	*auf*	to open	*closed*	*open*
ausstrecken	*kurz*	*lang*	to extend	*short*	*long*
abschneiden	*lang*	*kurz*	to cut	*long*	*short*
absteigen	*oben*	*unten*	to dismount	*up*	*down*
klettern	*unten*	*oben*	to climb	*down*	*up*
verpatzen	*gründlich*	*oberflächlich*	to mess up	*thorough*	*perfunctory*
intensivieren	*oberflächlich*	*gründlich*	to intensify	*perfunctory*	*thorough*
beschützen	*riskant*	*sicher*	to protect	*risky*	*safe*
pokern	*sicher*	*riskant*	to gamble	*safe*	*risky*
entfernen	*erfasst*	*unregistriert*	to delete	*recorded*	*unregistered*
speichern	*unregistriert*	*erfasst*	to record	*unregistered*	*recorded*
verelenden	*reich*	*arm*	to pauperize	*rich*	*poor*
erben	*arm*	*reich*	to inherit	*poor*	*rich*
aufbrausen	*heftig*	*sachte*	to erupt	*gentle*	*fierce*
abklingen	*sachte*	*heftig*	to decay	*fierce*	*gentle*
aufknöpfen	*angezogen*	*entkleidet*	to unbutton	*dressed*	*undressed*
bedecken	*entkleidet*	*angezogen*	to cover	*undressed*	*dressed*
heimkehren	*fern*	*nah*	to come home	*far*	*near*
wegfahren	*nah*	*fern*	to leave	*near*	*far*
abschminken	*markant*	*unauffällig*	to remove make-up	*distinctive*	*inconspicu-ous*
hervorheben	*unauffällig*	*markant*	to accentuate	*inconspicu-ous*	*distinctive*

German Version			English Translation		
Event	**Antonym 1**	**Antonym 2**	**Event**	**Antonym 1**	**Antonym 2**
einsperren	*außerhalb*	*innerhalb*	to imprision	*outside*	*inside*
verlassen	*innerhalb*	*außerhalb*	to exit	*inside*	*ouside*
verraten	*geheim*	*öffentlich*	to betray	*sectret*	*public*
verbergen	*öffentlich*	*geheim*	to hide	*public*	*secret*
auseinander-nehmen	*montiert*	*zerlegt*	to disassemble	*assembled*	*fragmented*
zusammen-fügen	*zerlegt*	*montiert*	to assemble	*fragmented*	*assembled*
ausklingen	*laut*	*leise*	to fade away	*loud*	*quiet*
verstärken	*leise*	*laut*	to amplify	*quiet*	*loud*
abtauchen	*oberhalb*	*unterhalb*	to descend	*above*	*underneath*
aufsteigen	*unterhalb*	*oberhalb*	to ascend	*underneath*	*above*